CAAM 334

MATRIX ANALYSIS IN DATA SCIENCE

Spring 2022 · Rice University

Lectures: MWF 10:00AM - 10:50AM, DCH 1075

Instructor: Mario Bencomo (mjb6@rice.edu), DCH 3022

Office hours: Thursdays 4:00PM - 5:00PM, or by appointment

Webpage: https://canvas.rice.edu/courses/46931

Course summary

This is an introductory linear algebra course with some applications in data science. This course covers solutions of linear systems of algebraic equations, the Fundamental Theorem of Linear Algebra, linear least squares problems, eigenvalues and eigenvectors of matrices, singular value decomposition, and several application problems. Computational examples and considerations will also be explored, primarily through Matlab/Python.

Learning outcomes

- ◇ Mathematical literacy, particularly in the field of linear algebra.
- ◇ Theoretical and practical knowledge for solving linear algebra problems.
- ◇ Working knowledge of LaTeX.

Prerequisites

- ◇ Multivariable calculus (MATH 212 or MATH 222) and basic Matlab/Python programming skills (CAAM 210 or COMP 140).
- ◇ Cannot register for CAAM 334 if student has credit for CAAM 335.

Text

- ◇ *Lecture Notes for CAAM 334/335: Matrix Analysis*, Fall 2020 (available on Canvas)
- ◇ *Linear Algebra in Situ*, January 20201 edition (available on Canvas)

Lectures

Students are expected to complete relevant reading assignments ahead of lectures to maximize in-class active learning experiences. Attendance is highly recommended. The instructor reserves the right to enforce attendance if unreasonably low attendance is observed.

Canvas

Canvas will be the primary source for course content. Almost all assignments will be administered, submitted, and graded through Canvas.

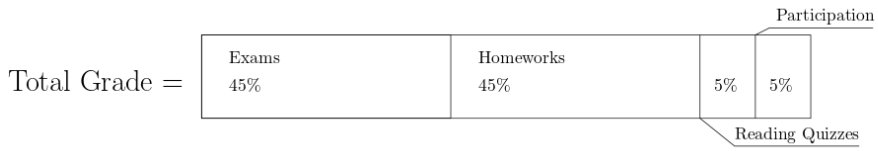
Communication Plan

- ◇ Canvas *Announcements* will be used to communicate in mass with the entire class on updates and appropriate course content.
- ◇ Canvas *Discussions* will be used as a means for students to pose content related questions to the instructor as well as the rest of the class. Students are welcome to contribute to discussions by asking or answering questions, but it will not be mandatory nor a component of their grade.
- ◇ Email is the preferred and reliable line of communication with the instructor for individual matters. Keep in mind that an immediate reply may not be guaranteed outside of working hours (9am-5pm weekdays).

◇ In general, students should not be contacting graders outside of Canvas.

Assignments and Grades

◇ Total grade breakdown:



◇ *Exams:* Three exams will be administered throughout the semester (including finals week), each equally weighted toward the final grade.

◇ *Homeworks:* Weekly assignments consisting of theoretical and computational problem sets. Collaboration is strongly encouraged, however, submitted write-ups must be individual's own work; see honor code policy below for a statement on plagiarism. Computational problems will require programming in Matlab/Python and submission of code for verification.

◇ *Reading Quizzes:* Canvas administered quizzes prior to lectures to motivate completion of reading assignments. These quizzes also serve as a diagnostic tool for the instructor and help shape upcoming lectures. Expect roughly two reading quizzes per week.

◇ *Participation:* Students will receive participation points for filling out surveys as well as attendance and participation during specified lectures.

Remark: Letter grades are assigned based on standard grade distributions.

Use of LaTeX

Homeworks and exams are NOT required to be typed up, unless stated otherwise. However, students are encouraged to submit typed up homeworks and will receive at most 5% extra-credit for doing so, though the maximum grade given will be capped at 100%.

Use of MATLAB/Python or other

MATLAB/Python or other (i.e, any form of computer assistance in performing calculations) will only be allowed for computational problems explicitly specified in an assignment. Students are welcome to modify code from in class examples or help each other out. See honor code policy below for a statement on plagiarism and improper use of MATLAB/Python or other.

Regrading

Students are welcome to inquire about graded assignments, either for clarification or if they suspect a mistake was made. For simple queries, leave a comment on the assignment (through Canvas) and the grader/instructor will reply back. Alternatively, you may email the instructor. You have up to 1 week after grades have been submitted to reach out for a regrade.

Policies and Exemptions

Assignment time-lines are constructed to be manageable and provide structure that reinforces the lecturing schedule, thus, late submissions are discouraged. That being said, the following policies and exemptions offer some flexibility so that students may deal with unexpected circumstances on their own terms without having to contact the instructor.

◇ *Late Homeworks*

- ▸ In general, only homeworks may be submitted late.

- ▸ Canvas will specify a "Due" date which is the date assignments must be submitted by to be considered on-time. Canvas will also specify "Available" dates which show the dates an assignment is available. Assignments submitted after the last available day will in general not be accepted.
- ▸ Assignments submitted after the due date but before the last available date are considered late. For homework assignments, the window for submitting late work is typically 48 hours after the due date. If the due date and the last available date coincide this implies late assignments are not accepted. Always check dates on Canvas to see if a particular assignment may be submitted late.
- ▸ The first three late homework submissions will not be penalized, hereafter referred to as the "3 homework extensions."
- ▸ Starting from the 4th late homework and on, there will be an incremental penalty specified by the following formula,

$$\text{pernalty} = (x-3) \times 10\%, \quad x \geq 4,$$

  where x is the number of late homework submissions during the semester.
- ▸ It is advised that students reserve their 3 homework extensions for emergencies or towards the end of the semester. Additional extensions will only be granted in emergencies and if the student can justify their previously used extensions, otherwise the instructor may retroactively penalize assignments.

◇ *Dropping Grades*
- ▸ The lowest homework grade will be dropped.
- ▸ The lowest three reading quizzes will be dropped.

◇ *General Exemptions*

It is emphasize that the policies highlighted above are meant to accommodate students during minor emergencies. Further accommodations for major emergencies will be considered on a case by case basis and may require documentation. Please contact the instructor as soon as possible if the situation should arise.

◇ *Honor Code Violations and Plagiarism*
- ▸ It is an honor code violation to consult with solutions from previous sections for this course, other solution manuals, or online tutoring services.
- ▸ When collaborating on permissible assignments, it is suggested that students avoid interchanging finalized solutions but instead share and discuss the mathematical concepts and their problem solving approach in order to avoid issues with plagiarism.
- ▸ It is an honor code violation to submit code or solutions which have, in all or in part, been copied from another student or other non-sanctioned sources.
- ▸ It is an honor code violation to use MATLAB/Python or other computational resources (i.e., symbolic toolkits) to substitute work that is meant to be carried out by hand. Problems that require MATLAB/Python will be explicitly labeled, otherwise assume the computations must be done by hand.

◇ *DSS Accommodations*

Any student with a disability requiring accommodation in this course is encouraged to contact the instructor during the first week of class, and also to contact Disability Support Services in the Ley Student Center.

◇ *Title IX Statement*

Rice University cares about the wellbeing and safety of students. Rice encourages any student who has experienced an incident of harassment, pregnancy discrimination, gender discrimination, or relationship, sexual, or other forms interpersonal violence to seek support through the SAFE Office. Students should be aware when seeking support on campus that most employees, including ourselves, as the instructors/TA, are required by Title IX to disclose all incidents of non-consensual interpersonal behaviors to Title IX professionals on campus who can act to support that student and meet their needs. For more information, please visit safe.rice.edu or email titleixsupport@rice.edu.

Some advice ...
Put in your due diligence, but do no isolate yourself if you need help.

- ◇ Reach out if you need accommodations. The sooner the more options there will be.
- ◇ Make use of course resources, study group, office hours.
- ◇ Manage your time wisely (work smarter not just harder).

Tentative Schedule: The following schedule is intended to give a general idea of the progression of the course. The topics for each week are tentative and subject to change with advance notice. Please see `https://registrar.rice.edu/calendars/spring22` for a more thorough list of University-wide important dates.

Block I: Introduction

- ◇ Topics: introduction to the course, matrix-vector computations, basic math proof structures

Block II: Solving $Ax = b$

- ◇ Topics: Gaussian elimination, matrix inverses, LU decomposition, determinants

Block III: Fundamental Theory

- ◇ Topics: subspaces in $\mathbb{R}^n$, range and null spaces of matrices, the four fundamental subspaces, the fundamental theorem of linear algebra (FToLA)

Block IV: Beyond the Fundamentals

- ◇ Topics: vector spaces, linear mappings, linear least squares (theory and applications), projections, Gram-Schmidt orthogonalization process, QR decomposition
- ◇ Applications: linear regression, data fitting

Block V: Eigenvalue Decomposition

- ◇ Topics: complex numbers, eigenvalues and eigenvectors, diagonalization of matrices and applications
- ◇ Applications: dynamical systems, difference equations

Block VI: Singular Value Decomposition

- ◇ Topics: the singular value decomposition (SVD) of matrices, relation to FToLA, pseudo-inverses, regularized least squares
- ◇ Applications: deconvolution, data compression

Addendums:

- *Exam 3 Options*
  1. Complete Exam 3, which is cumulative and will be administered online (though there may still be a timed-component).
  2. If HW10 is not your dropped HW, then Exam 3 is optional. If you decide not to take Exam 3, then Exams 1 and 2 will account for 45% of your grade.
- *Letter Grade Distributions*
  - A+: [97,100]
  - A : [93,97)
  - A– : [90,93)
  - B+: [87,90)
  - B : [83,87)
  - B– : [80,83)
  - C+: [77,80)
  - C : [73,77)
  - C– : [70,73)
  - D+: [67,70)
  - D : [63,67)
  - D– : [60,63)
  - F : [0,60)